1-1-2019

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10.1080/23311843.2019.1603418
Kuranchie, F. A., Angnunavuri, P. N., Attiogbe, F., & Nerquaye-Tetteh, E. N. (2019). Occupational exposure of benzene, toluene, ethylbenzene and xylene (BTEX) to pump attendants in Ghana: Implications for policy guidance. Cogent Environmental Science, 5(1), 1603418.
https://doi.org/10.1080/23311843.2019.1603418

cogent environmental science

ENVIRONMENTAL HEALTH | REVIEW ARTICLE

Occupational exposure of benzene, toluene, ethylbenzene and xylene (BTEX) to pump attendants in Ghana: Implications for policy guidance

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Received: 21 October 2018
Accepted: 02 April 2019
First Published: 04 April 2019

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Reviewing editor:
Geun Young Yun, Kyung Hee University, Seoul, Republic of Korea

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Abstract: Gasoline plays an important role as fuel for engines, but its use is replete with a high probability of adverse health to persons along the distribution chain, especially pump attendants. This study is a systematic review of the literature on gasoline exposure and the specific risks of adverse health on pump attendants by benzene, ethylbenzene, toluene and xylene (BTEX) to instigate policy in Ghana. A careful review of the literature indicates that pump attendants are at risk of developing cancer and non-cancer health hazards. This is particularly so in Ghana due to poor safe work practices and controls at pump stations. Occupational and environmental health and safety is not legislated in Ghana, there is poor awareness of gasoline hazards (especially BTEX) among pump attendants, and poor pump infrastructure controls for BTEX exposure mitigation. Although Ghana has revised the motor gasoline standard to reflect 1%v/v benzene and 35%v/v maximum volatile aromatic compounds, the absence of an exposure standard for BTEX compounds makes it necessary to monitor these compounds. In the absence of

ABOUT THE AUTHOR

My main research background is providing environmental interventions to solve industrial related problems to foster sustainable development in the industry and society. This work on BTEX exposure on pump attendants is part of the broad research theme for my research group on environmental management and sustainability.

PUBLIC INTEREST STATEMENT

Gasoline plays an important role as fuel for engines, but its use has health concerns and implications for all stakeholders involved in usage, especially fuel stations pump attendants. This study has reviewed the literature on gasoline exposure and its associated risks on pump attendants by benzene, ethylbenzene, toluene and xylene (BTEX) to call for favourable policy in Ghana. Findings reveal that pump attendants are at risk of developing cancer and non-cancer health hazards. This has crucial implications for Ghana due to poor safe work practices and controls at pump stations. There is poor awareness of gasoline hazards (especially BTEX) among pump attendants, and poor pump infrastructure controls for BTEX exposure mitigation. Although Ghana has revised the motor gasoline standard to reflect 1%v/v benzene and 35%v/v maximum volatile aromatic compounds, the absence of permissible exposure limit for BTEX compounds makes it necessary to monitor these compounds to instigate policy for awareness and BTEX exposure minimization.

a national occupational, health and safety legislation, corporate organizations must establish specific policies that are committed to minimizing exposure to BTEX compounds including personal protection, adequate engineering controls, and tailored management practices.

Subjects: Environment & Philosophy; Environment & Society; Environment & Theory; Environment & the City; Environmental Change &Pollution

Keywords: BTEX; pump attendants; gasoline; occupational exposure; policy guidance

1. Introduction

Petrochemical industries, including pump stations, provide an exposure scenario that increases the vulnerability of front line staff to gasoline-related ill-health (Azari et al., 2012). Spiralling global population coupled with an increasing appetite for petrol and other petrochemical products has meant an increasing exposure to exposed populations.

BTEX, the acronym for benzene, toluene, ethylbenzene and the isomers of xylene, which are added as anti-knock agents to petrol (Chinwenwa, 2012; ODH, 2007; Speight, 2015), represent some of the most hazardous components of gasoline (Chilcott, 2007; Fowles, 2015; Godish, 2013; Heibati et al., 2017; Sirotkin & Halim, 2017). Vehicle refuelling is a major source of benzene exposure among non-smoking people, the extent of emission being a direct function of the temperature and composition of the liquid, the headspace of the tank, and the volume of fuel dispensed (Bhardwaj, Rani, & Kumar, 2017).

Numerous health assessment studies of BTEX compounds have linked them to serious developmental, neurological and many chronic health conditions, and recommend the need to reduce their exposure to human populations (Salvato, Nemerow, & Agrady, 2003; Olawoyin, 2012; Edokpolo, Yu, & Connell, 2014; Lv, Song, Zhang, Mei, & Ye, 2014; Edokpolo, Yu, & Connell, 2015b; Harati, Shahtaheri, Karimi, & Azam, 2016b; Hazrati, Rostami, Fazlzadeh, & Pourfarzi, 2016; Stolark, 2016; Zoleikha, Mirzaei, & Roksana, 2017; Cruz, Alves, Santos, Esteves, & Gomes, 2017).

According to toxicological studies, all BTEX compounds are neurotoxins and irritants (Chinwenwa, 2012); however, IARC considers benzene and ethyl benzene as assured Class 1A and probable human carcinogens, respectively (Åkerström, Johannesson, Bergemalm-Rynell, & Bo Strandberg, 2006; Chaudhary & Kumar, 2012; IARC Monographs, 2015). While toluene and xylene are not classified as cancer conveners, they cause significant cell growth inhibition (Ekpenyong & Asuquo, 2017), depression of the CNS, and irritation of eyes and throat (Åkerström et al., 2006). Petrol itself has been classified as a Category B suspected human carcinogen (Alyami, 2016; Fowles, 2015) and Category 1B mutagen (Hinwooda et al., 2007; Lucenir, Almeida, Roberto, Filho, & Alves, 2012). Petrol vapour is the major air pollutant at pump stations, and the largest contributor to atmospheric BTEX concentrations (Bolden, Kwiatkowski, & Colborn, 2015; Edokpolo, Yu, & Connell, 2015a). As well as being toxic, the BTEX compounds also contribute to the formation of secondary air pollutants, including ozone, ultrafine particulate matter, and polycyclic aromatic hydrocarbons which are implicated in global warming and adverse health effects (Masih, Lall, Taneja, & Singhvi, 2017; Som, Mukherjeea, & Sen, 2011). As the auto and fuel industries look for alternative sources of octane, the impacts of BTEX compounds on both health and the environment need to be considered in the face of these adverse findings against them.

Exposure of pump attendants to gasoline vapour during vehicle refuelling has raised health concerns, especially in countries with warmer climates (Hinwooda et al., 2007; Kitwattanavong, Prueksasit, Morknoy, Tunsaringkarn, & Siriwong, 2013). This is primarily due to increased gasoline vaporization at higher ambient temperatures and the increased risk of higher inhalation uptake compared to temperate countries (Alyami, 2016; Campo, Rossella, Mercadante, & Fustinoni, 2016;

Fedrizzi, Cagliari, Teixeira, Finotti, & Filho, 2013; Hinwooda et al., 2007). The presence of a canopy over the pump, such as a roof, also increases the ambient flux of VOCs around the station (Alyami, 2016).

Available reports indicate greater risk due to exposure of BTEX to pump attendants than other Occupations (Campo et al., 2016; Chaudhary & Kumar, 2012; Cruz et al., 2017; Heibati et al., 2017; Kitwattanavong et al., 2013; Moolla, Curtis, & Knight, 2015; Singh, Ramteke, Juneja, & Pandya, 2013;).

Exposure to BTEX at fuel stations is largely dependent on the technical specification of the gasoline especially its benzene content (Sousa et al., 2011), and the engineering controls in operation (Som et al., 2011). It has been found that high levels of ambient BTEX flux exist during refilling of underground gasoline storage tanks at filling stations in Thailand (Sairat, Homwuttiwong, Homwutthiwong, & Ongwandee, 2015). Petrol attendants are at risk of exposure through inhalation and dermal absorption, and in rare cases, ingestion.

Exposure to chemical hazards in the workplace is affected by public policy, regulation, mechanical controls, administrative and behavioural measures like systems of work, supervision and training. Good Occupational, Social and Health and Safety (OSHS) practices should be used by employer and employees to control risk, minimize exposure and protect the health of workers and non-workers, who are at risk of exposure.

2. Significance of study

An estimated 0.07% of workers globally die each year from work-related ill-health and injuries, whilst about 5.3% of persons suffer from work-related diseases (Ekpenyong & Asuquo, 2017). BTEX constitute one of the most ubiquitous and hazardous groups of anthropogenic ambient air contaminants of concern (Bolden et al., 2015). Environmental health research suggests that even a low-level exposure to the BTEX complex from gasoline additives, other petroleum products, and industrial solvents, as stated in Table 1 are capable of causing negative developmental, reproductive (Sirotkin & Halim, 2017) and immunological responses, and systemic toxicity (Stolark, 2016).

BTEX compounds are genotoxic in nature (Makwela, 2013; Villalba-Campos, Chuaire-Noack, Sánchez-Corredor, & Rondón-Lagos, 2016; Xie et al., 2010; Xiong et al., 2016) due to their potential to cause malformation of chromosomal and/or genetic aberrations (Ekpenyong & Asuquo, 2017). Genotoxicity has been found at higher levels in gasoline station workers than in control groups and may pose hazardous cancer and non-cancer risks to workers (Ekpenyong & Asuquo, 2017; Hafizal, Hamid, Jumah, Latif, & Kannan, 2017; Xiong et al., 2016). BTEX compounds are known as neuro- and hepato-toxins and cause significant cognitive and behavioural effects in occupationally exposed groups. (Santiago et al., 2014). It has been reported that there is a higher than recommended levels of area and personal BTEX concentrations and this has caused significant pulmonary impairment among pump attendants in Saudi Arabia (Ismail, Behaedi, Balkhyour, & Hassan). Different organizations have also reported with different allowable exposure limits for BTEX as shown in Table 2.

Table 1. Average concentration of potentially neurotoxic constituents of liquid petrol and vapour (Chilcott, 2007)

	Concentration (%w/w)	
Chemical	**Liquid**	**Vapour**
Benzene	2.5 (0.2–4.7)	1.77 (0–5.4)
1, 3-Butadiene	<0.1	0.65 (0–4.6)
Ethylbenzene	2.6 (1.0–5.4)	0.009 (0–0.1)
n-Hexane	2.5 (0.8–5.4)	1.37(0–6.5)
Toluene	11.4 (2.7–21.0)	1.63(0–7.1)
Xylene	10.6 (5.8–15.8)	0.48(0–2.1)

Table 2. Typical exposure limits for BTEX

Compound	MW	BP	OSHA (ppm)		NIOSH (ppm)		ACGIH TWA (ppm)	
	(g/mol)	(°C)	STEL	TWA	STEL	TWA	STEL	TWA
Benzene	78	80.1	5	1	1	0.1	2.5	**0.5**
Toluene	92	110.6	300	200	150	100		20
Ethyl—Benzene	106	136.2		100	125	100		20
Xylene	106	138.3–144.4		100	150	100	150	100

Pump stations in Ghana are man-manned at present with vapour recovery technologies still alien to the system. Whilst the Ghana standard for benzene and total aromatics content in motor gasoline has been revised to reflect category 4 standard of the African Refiners Association (AFRI-4) specification (GSA, 2017), no exposure standard exists and exposure data is lacking. The need for regulatory guidance on BTEX exposure as an occupational hazard has never been considered so critical in Ghana despite the numerous pump stations springing up across the nation. It is essential to investigate acceptable levels of BTEX, as this area of research is vital if the health and safety of occupationally exposed workers are to be considered.

3. Methodology

This is a systematic review of BTEX compounds and their adverse health effects on pump attendants. Potential policy dimensions in Ghana were also studied and discussed. Scopus-listed journals were extensively canvassed using the keywords BTEX, occupational health, Ghana, pump attendants, gasoline, and imported to Mendeley. Other sources of information including reports, thesis write-ups, conference proceedings and books were retrieved and exported to Mendeley as well to avoid duplications. The document was screened and evaluated for specific information on gasoline composition and health effects, BTEX compounds and their health effects and policy guidance in a Ghanaian national context. General conclusions were then drawn on the exposure of pump attendants to gasoline BTEX, and the role of legislation and policy.

4. Results and discussion

4.1. Background of occupational health safety (OSH) in Ghana

The Petro-chemical industry is not only a major employer in Ghana, but also provides significant exposure to workplace stressors (Baffuor & Abena Offe, 2017). Ghana's current OSH Policy and existing legislation providing for the safety, health and well-being of employees such as the Ghana Labour law Act 2003, Act 651, and ILO Convention number 155 (1981) are limited in scope, prescriptive, and disjointed in their applications (Yankson, 2012).

There is limited national OSH policy that regulates downstream petroleum workers in Ghana either, especially pump attendants, and the control of environmental toxins from fuel emissions (Baffuor & Abena Offe, 2017). Few ones existing are fragmented and sector-based. The Department of Factories Inspectorate, established by the Factories, Offices and Shops Act of 1970 (Act 328) (Republic of Ghana, 1983; Achaw & Boateng, 2012; Dwumfour-Asare & Asiedu, 2013) and mandated to promote and monitor occupational health and safety, has been chronically under-resourced and ineffective over the years (Achaw & Boateng, 2012).

The policy statement of Occupational Safety and Health Administration (OSHA) of the USA opines that worker health and safety should be integrated into the growing movement toward sustainability and corporate responsibility (Williams et al., 2007). In Ghana, employers are required by the Ghana Labor Act (Asumeng, Afful, & Badu Agyemang, 2015) to ensure their employees are protected against work-related injuries, illnesses or hazards. Employees have a responsibility to comply with employers' standard operating procedures which must incorporate Safety and Health policies. Unfortunately, stakeholders are more concerned with economic benefits rather than safety and health (Ansah & Mintah, 2012.).

Work environments should be made safe, favourable and conducive to enhance productivity and economic prosperity for both employer and employee. Good health at work helps improve employee's health in general and the productivity and competitiveness of businesses. Whilst the economic cost of health and safety at the workplace can reduce bottom-line profitability of companies, effective and efficient health and safety policies improve the performance of employees and the organization, by reducing costs associated with accidents, disabilities, absenteeism, illness and long-term incapacitation.

4.2. Composition of gasoline

Motor gasoline is a highly flammable and potentially explosive mixture of liquid hydrocarbons that is used as fuel in internal combustion engines such as motor vehicles (ATSDR, 1995; Speight, 2015). Gasoline is distilled between C_4 and C_{12} with an upper boiling point of 216°C (Speight, 2015; Swick, Jaques, Walker, & Estreicher, 2014). Gasoline life cycle is shown in Figure 1. Its composition varies depending on the amount of aliphatic and aromatic hydrocarbons (Lagorio et al., 1994) as well as additives and blending agents (Lyons, 1996). Various gasoline compositions exist depending on various factors such as geographic location, season, performance requirements, refining process and blending stocks (Hazrati, Rostami, Fazlzadeh, & Pourfarzi, 2016). The typical hydrocarbon content of liquid gasoline is approximately 60% to 70% alkanes, 5% to 10% alkenes, and 25% to 30% aromatics including BTEX (Pope & Rall, 1995). BTEX typically makes up about 18% gasoline (ODH, 2007) but the benzene content of petrol ranges between 1% and 5% (Speight, 2015). Gasoline may also contains various additives that improve its performance and stability as a motor fuel (Pope & Rall, 1995).

4.3. Exposure to gasoline

Workers in the petrochemical industry, in general, are at greater risk of exposure to gasoline (Pope & Rall, 1995). Persons living near gasoline facilities also have a potential exposure. Gasoline exposure to the general population occurs primarily through vapour inhalation during automobile refuelling and vehicle exhaust emissions (ATSDR, 1995; Pope & Rall, 1995). It is usually perceptible at 0.25ppm of air but can be as high as 99 ppm at gas filling stations (ATSDR, 1995). Gasoline vapour is released into the air during refining, gasoline transfer (Lim et al., 2014), and leaks from storage containers and loading equipment (Zoleikha et al., 2017), as well as during refuelling of vehicles (Moolla, 2015).

Human exposure to liquid gasoline occurs by unintentional or intentional ingestion, accidental skin contact, or by misuse of the solvent (Chilcott, 2007). Contaminated water is a potential source of gasoline exposure for the general public (Pope & Rall, 1995). Gasoline easily migrates into groundwater through the soil surrounding a spill or a leaking underground storage tank or pipeline (TOSC, 1989). Inhalation is the major pathway of human exposure to BTEX compounds (Esteve-Turrillas, Pastor, & de la Guardia, 2007). Typical 8-h benzene exposure concentrations in gasoline distribution and retail chain average less than 1 ppm, although exposures can reach 2–3 ppm for shorter periods (Alyami, 2016; Huang et al., 2013).

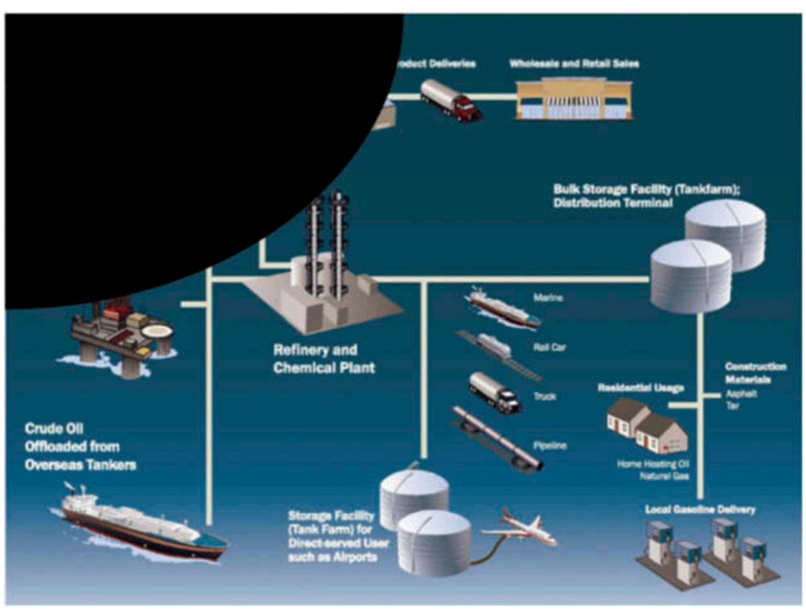


Figure 1. Gasoline Life cycle (Swick et al., 2014).

4.4. Risks of exposure to gasoline

The dangers of gasoline exposure are caused by chemicals in the gasoline mixture such as benzene, toluene, ethylbenzene, xylenes (ATSDR, 1995) and methyl tertiary butyl ether (MTBE) (Craft & Chiu, 1997). The major systemic effect of acute gasoline exposure is CNS depression (ATSDR, 1995; Chilcott, 2007). These symptoms may include facial flushing, ataxia, vertigo, mental confusion, headaches, blurred vision, slurred speech, and difficulty in swallowing. At very high concentrations, coma and death can occur within a few minutes. Respiratory tract irritation can also occur at high concentrations (Philip et al., 2006; Pope & Rall, 1995). Haematopoietic effects including anaemia and hypochromia can occur to the presence of benzene in gasoline (Riaz, Riaz, & Ijaz, 2014). IARC classified benzene as a human carcinogen due to the presence of benzene and 1,3-butadiene in gasoline (ATSDR, 1997; Drew, Harkins, O'Connor, Paharagood-Wade, & Tucker, 2000; Mahi, 2010; USEPA, 1976). Chronic abuse of gasoline through sniffing has been reported to cause cardiac abnormalities (Pope & Rall, 1995). Cognisant of the harmful effect of gasoline, various governments have enacted legislation and established policies that limit the amount of gasoline additives to minimize environmental and public health consequences along the gasoline life cycle chain (Swick et al., 2014).

4.5. BTEX as an environmental pollutant and health hazard

BTEX are mono-aromatic non-methane volatile organic pollutants (Brajenović, Karačonji, & Bulog, 2015) emitted into the ambient air from different sources including petrol, diesel, vehicular fumes, coal tar, cigarette smoke, paint, etc. (Słomińska, Konieczka, & Namieśnik, 2014). They are non-polar and highly lipophilic thus, aiding their absorption and deposition in internal organs and subcutaneous tissue (Tohon, Fayomi, Valcke, Coppieters, & Bouland, 2015). BTEX compounds have very high vapour pressures and usually evaporate quickly into the air especially at higher temperatures (Speight, 2015). BTEX can also dissolve in water, and may be found in surface and groundwater at contaminated sites or in close proximity to natural oil, coal and gas deposits (TOSC, 1989).

The most significant increase in energy consumption and greenhouse gases emissions are taking place in metropolitan cities which have rapidly expanding populations enjoying higher living standards and material affluence than persons living in rural areas and smaller cities. VOCs are precursors of ozone and other photochemical oxidants in the upper atmosphere and may contribute to global warming. Metropolitan cities, which contribute the largest emissions of VOCs, thus have significant contribution towards the total national as well as global emission of greenhouse gases including CO2 and VOCs (Som et al., 2011).

VOCs cause many adverse effects to human health even at lower concentrations and are designated as the most toxic gasoline-derived compounds to human health (Cakmak et al., 2014). Because of their high reactivity and volatility, workers are constantly exposed through inhalation, dermal absorption, and ingestion. Amongst these three routes, inhalation is the major pathway due to their relatively high vapour pressures (Philip et al., 2006). These exposures can be accidental or intentional and are usually insidious in nature (Olawoyin, 2012).

BTEX compounds show very high potential for bioaccumulation and are implicated in many cancer and tumour cases in humans (Carballo-Pat et al., 2013; Olawoyin, 2012). Through clinical and epidemiological studies. benzene has been confirmed as a human carcinogen by the USEPA (USEPA, 1989), the European Commission (EC., 2008; ECHA., 2011; Ntp, 2009), and ACGIH (Moolla et al., 2015). When present beyond certain threshold concentrations as pointed out in Table 1, BTEX compounds are immediately dangerous to life and health (Moolla, 2015; Moolla et al., 2015). Acute health effects of BTEX vapours are eye, nose, and skin irritation and effects on the central nervous system, such as headache, tiredness, drowsiness, dizziness and even death.

Chronic exposure poses risk of cancer, damage to the liver, kidneys, heart, lungs, nervous system, bone marrow and blood production. Benzene produces mutagenic properties and exposure to it has been linked to leukaemia (Som et al., 2011). Benzene can also cause excessive bleeding and can affect the immune system, increasing the risk of infection. A study in Thailand

(Tanasorn, Kalaya, & Anusorn, 2012) supported the hypothesis that chronic BTEX exposures were implicated in decreasing testosterone level in the reproductive system as well as lower kidney function. Wiwanitkit (2006) presented benzene as a spermato-toxin capable of causing deformities during gametogenesis in men. Cakmak and colleagues (Cakmak et al., 2014) established BTEX as reproductive toxicants capable of acting as environmental endocrine disruptors that can induce female infertility, spontaneous abortion, birth defects, and intra-uterine growth retardation. Their findings also indicated that females exposed to BTEX had a significantly higher prevalence of menstrual disorders, low serum estradiol, and deranged reproductive hormone profiles.

Xylenes are developmental toxins, and chronic exposure results in tardy development, distorted enzyme activities and reduced fatal body weight (Olawoyin, 2012).

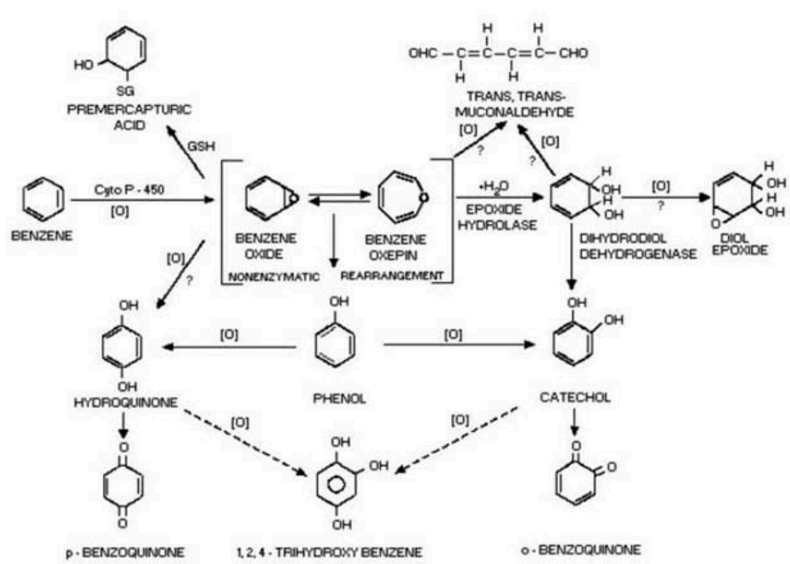
According to WHO the lifetime risk of chronic leukaemia for benzene exposure of 1 µg/m3 is 4.4–7.6 × 10–6 (WHO, 2010, 2000). The USEPA, states that a cancer risk above 1 × 10–6 (1 in 1,000,000) is unfavourable as it significantly increases carcinogenic potential in humans (Tanasorn et al., 2012; USEPA, 1976). Permissible exposure limit values suggested by OSHA for benzene give a probability of cancer risk for 878 workers in a million, and a hazard quotient of 19 (Som et al., 2011). Research has shown that individuals have developed and died of leukaemia when exposed to benzene for periods varying from 5 years to 30 years (Kitwattanavong et al., 2013; Tanasorn et al., 2012).

4.5.1. Benzene

Benzene exists at room temperature as a clear, colourless-to-yellow liquid with an aromatic odour. It is highly lipophilic (Pope & Rall, 1995), but slightly miscible in water (Tanasorn et al., 2012; Tohon et al., 2015). It is a major commodity chemical (Pope & Rall, 1995) and has ubiquitous applications in the chemical, solvent and drugs industries, and in the refining of gasoline (Lv et al., 2014; Melikian et al., 2002). It is also used as material in the synthesis of ethylbenzene, cyclohexane, nitrobenzene, detergent alkylate, and chlorobenzenes (OSHA, 2002).

Workers employed in industries using or producing benzene have the greatest likelihood of exposure. Benzene is absorbed through inhalation, ingestion and/or dermal absorption and then converted to toxic metabolites by mixed-function oxidases (MFO) in the liver and bone marrow (Philip et al., 2006; Pope & Rall, 1995). The metabolites may bind covalently to cellular macromolecules, causing disruption of cell growth and replication. The various pathways and metabolites are presented below in Figure 2. Alcohol may increase the rate at which toxic metabolites of benzene are formed (Pope & Rall, 1995).

Figure 2. Urinary metabolites of Benzene (INCHEM, 1993).



Benzene has been implicated in both acute and chronic poisoning with varying latency periods (Verma & Des Tombe, 2002). It is regarded as the most hazardous compound of the BTEX group and targets the CNS and haematopoietic systems (Pope & Rall, 1995). IARC and USEPA have independently classified benzene as a Group A and Class 1 human carcinogen, respectively, based on sufficient evidence of carcinogenicity from human studies (Edokpolo et al., 2014, 2015b). Acute myeloid leukaemia (Chinwenwa, 2012) in individuals exposed to benzene above action levels (Ntp, 2009). Non-cancerous toxicity of reproductive, immune, nervous, endocrine, cardiovascular and respiratory systems have also been reported in some studies (Bahadar, Mostafalou, & Abdollahi, 2014; Moro et al., 2017, 2015). Myalgia has been reported as a symptom of exposure to benzene vapours. Benzene may also affect the renal system (Collins, 2000), as kidney congestion has been found following fatal inhalational exposure. Benzene appears to affect the immune system, where workers have been shown to have decreased levels of leukocytes and circulating antibodies (OSHA, 2002).

Exposure to benzene may play a role in infertility in men, as workers have increased incidence of chromosomally defective sperm, which can lead to spontaneous abortions, mental retardation, and inherited defects in their children. An association may exist between mothers exposed to benzene and children with spina bifida (ATSDR, 2007a).

Benzene exposure can be as high as 349 $\mu g/m^3$ in industrial centres with heavy traffic, and 10 $\mu g/m^3$ at fuel pump stations. OSHA determined a Permissible Exposure Limit (PEL) of 3mg/l (1ppm) using toxicity studies (Lv et al., 2014). Major routes of exposure are oral and inhalation with a higher rate of retention in women than men and in tissues with high lipid content or placental materials (INCHEM, 1993).

4.5.2. Toluene

Toluene is a highly inflammable colourless liquid infinitely miscible in organic solvents. It is used as a chemical intermediate (INCHEM, 1985) in the manufacture of many industrial chemicals including benzoic acid, benzaldehyde, explosives, dyes and many other organic compounds (OSHA, 1998). It is also found in paints, paint/ink thinners, adhesives, perfumes, nail polish, and dyes. It is a natural component in gasoline but is also used as a gasoline additive (ATSDR, 2015).

The principal source of exposure to toluene in the general population is gasoline (Pope & Rall, 1995). Toluene is a toxic skin/eye irritant and a CNS depressant. OSHA reports mental confusion, loss of coordination, and unconsciousness above the STEL threshold (OSHA, 1998). Exposures above 200 ppm for 8 h causes fatigue, weakness, confusion, headache, dizziness and insomnia (ATSDR, 2015)

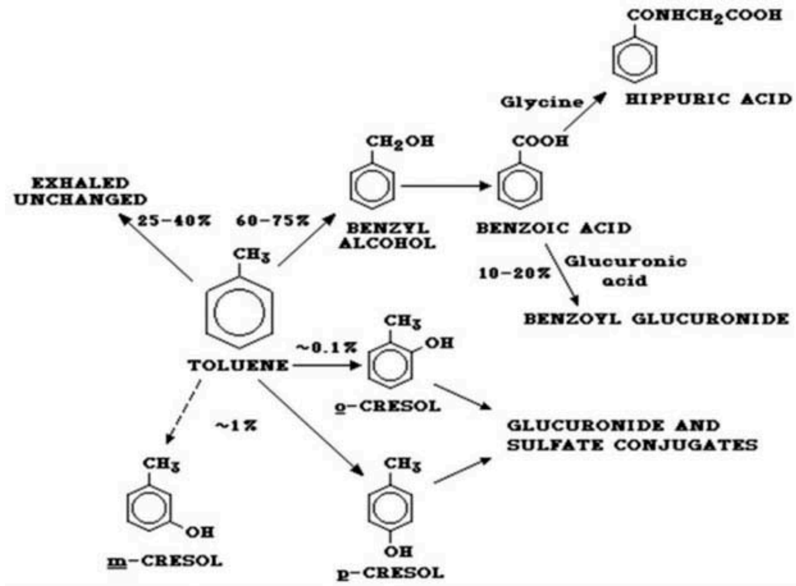
Toluene is converted to benzoic acid in the body, which is then conjugated with glycine in the liver to form hippuric acid. The hippuric acid is then excreted in the urine as shown in Figure 3 (ATSDR, 2004; INCHEM, 1985).

4.5.3. Ethylbenzene

Ethylbenzene is a flammable liquid that is totally soluble in organic solvents. Ethylbenzene is almost exclusively as a precursor for the manufacture of styrene and commercial xylenes (INCHEM, 1996; Phoslab, 2016).

It is well absorbed by the skin, lungs and gastrointestinal tract, and metabolized by hydroxylation of the two carbons of the side-chain (ATSDR, 2007b), followed by oxidation to mandelic acid, phenylglyoxylic acid and a range of minor metabolites that are excreted principally in the urine (INCHEM, 1996). It occurs naturally in crude oil but exposure can originate from anthropogenic refined products and the incomplete combustion of natural materials including forest fires and cigar smoke (INCHEM, 1996). Ethylbenzene is a skin and mucous membrane irritant. It has acute and chronic central nervous system effects that include vertigo, unconsciousness, tremors, and changes in respiration (OSHA, 1999). IARC has determined that long-term exposure to

Figure 3. Metabolism of Toluene in Human beings and animals (INCHEM, 1985).



ethylbenzene may cause cancer in humans (ATSDR, 2007b). Ethylbenzene is mainly excreted in the urine mainly as glucuronides as shown in Figure 4.

4.5.4. Xylenes

Xylene isomers of *m, o*, and *p*, differ only in the placement of the two methyl groups on the benzene ring. Xylenes are soluble in alcohol and ether but insoluble in water. They each have clear, colourless organoleptic properties at room temperature, however, *p*-xylene forms crystals at a relatively high temperature (Philip et al., 2006). Most mixed xylenes are used as additives in gasoline blends and as the raw material in the coating industry (OSHA, 1999).

Xylenes are eye, skin, and mucous membrane irritants and can cause respiratory, gastrointestinal, musculoskeletal, and nervous problems (Phoslab, 2016). Xylenes can also cause liver and kidney damage. Long-term risk of carcinogenicity has not been reported in experimental animals (OSHA, 1999). The ACGIH TLV-TWA was set at 100 ppm, and the STEL at 150 ppm, for mixed xylene isomers and for individual isomers. The main metabolites of the xylenes are the corresponding isomers of toluic acid (m-methyl benzoic acid) which is then conjugated with glucuronic acid and excreted in urine as presented in Figure 5.

Figure 4. Metabolic pathways of Ethylbenzene (INCHEM, 1996).

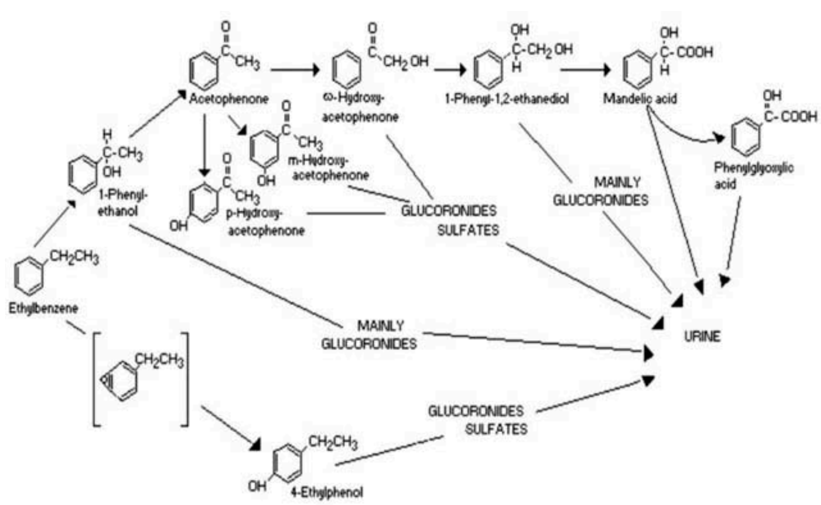
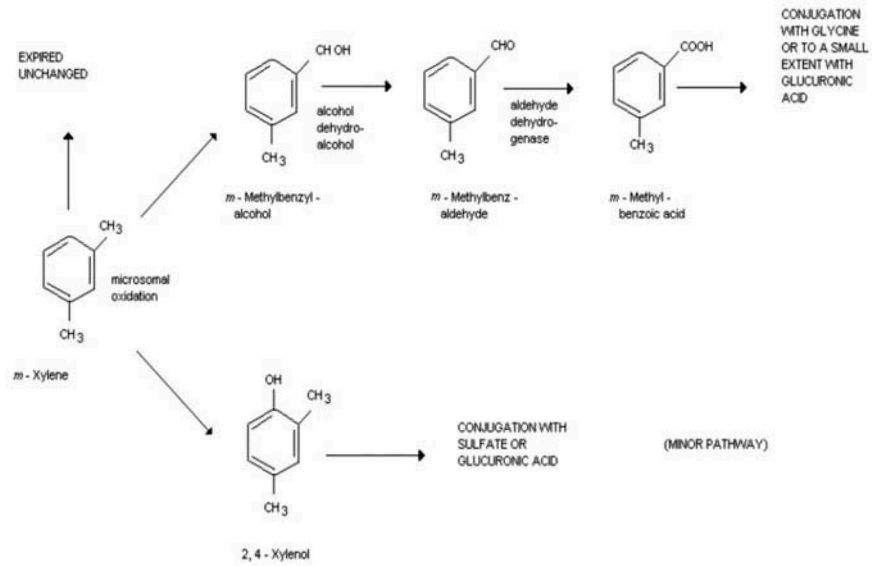


Figure 5. Biotransformation of m-xylene (INCHEM, 1997).



4.6. BTEX standards and regulation

Monitoring of these compounds has been legislated in many countries and air quality standards have been established (Alyami, 2016). Most countries now have occupational exposure limits (OEL) for BTEX at the workplace. In the United States, the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) and the OSHA Permissible Exposure Limit (PEL) standards are the most cited contaminant airborne standards (Cruz et al., 2017)

TLV-Time Weighted Average (TLV-TWA), TLV-Short Term Exposure Limit (TLV-STEL) and TLV-Ceiling (TLV-C) are in common use in North America and Europe.

In the European Union, the ambient air quality standard for benzene is 5-$\mu g/m^3$ annual-based time-weighted average (Badjagbo, Loranger, Moore, Tardif, & Sauvé, 2010). In occupational settings, the ACGIH recommends threshold limit values (TLVs)-TWA of 0.5 ppm. (1.6 $\mu g/m^3$) for benzene, 20 ppm. (75 $\mu g/m^3$) for toluene and ethylbenzene, and 100 ppm. (434 $\mu g/m^3$) for ethylbenzene and xylenes, respectively. The current 8-h TWA regulatory values for the workplace in the Province of Quebec, Canada, are 1 ppm. (3 $\mu g/m^3$) for benzene, 50 ppm. (188 $\mu g/m^3$) for toluene, and 100 ppm. (434 $\mu g/m^3$) for ethylbenzene and xylenes (Badjagbo et al., 2010).

According to OSHA (OSHA, 2002; Rosenthal et al., 1992), PEL for short-term exposure (STEL) to benzene is 5 ppm (16 µg/m3) for any 15-min period whilst the 8-h TLV-TWA is pegged at 1ppm. The National Institute of Occupational Safety and Health (NIOSH) has even lower exposure limit of just 1ppm over a 15-min period (STEL) and 0.1ppm over 8 h (TWA) (Rosenthal et al., 1992).

The Action Level (AL) for benzene, which indicates concentration that requires medical surveillance, increased industrial hygiene monitoring, or biological monitoring, is just 0.5ppm as an 8-h time-weighted average. The Recommended Exposure Limit (REL) for the National Institute for Occupational Safety and Health (NIOSH) is 0.1ppm TWA, and 1ppm STEL.

The severity of health effects depends on the duration, dose and frequency of exposure, as well as the general health of the individual. In 2014, WHO identified benzene as a major health concern in Africa, especially in occupational environments (Marc Guéniat, Harjono, & Andreas Missbach, 2016). Correa and co-workers (Correa, Arbilla, Marques, & Oliveira, 2012) reported that BTEX concentrations were appreciably higher in filling stations than what is found in locations with high vehicular flux. In north Africa, Kerchich and Kerbachi found higher than normal ambient air levels of BTEX compounds in the city of Algiers (Kerchich & Kerbachi, 2012).

Correa and colleagues reported that BTEX exposure directly increases with increasing temperature due to stronger fuel evaporation, which is the situation in most African nations (Correa et al., 2012).

An effective way to control exposure to BTEX compounds is through regulating their limits in consumer products (Guéniat et al., 2016). In Europe and the USA, benzene in gasoline is restricted to 1%. In many African countries, limits do not exist, and where they do, they can be as high as 5% (Guéniat et al., 2016).

Ghana has complied with AFRI-4 spec for 1% (v/v) max benzene in gasoline blends and other aromatics at 35% (v/v) max (GSA, 2017; ICF Int, 2009). Unfortunately, no exposure standards exist. However, the higher tropical ambient temperatures coupled with the high vapour pressures and longer half-lives of BTEX compounds make it imperative to continually monitor and assess BTEX risk among exposed populations. In addition, unusual work shifts which increase workers exposures to a minimum 18 h/day and the absence of a guiding OHS legislation make it even more necessary.

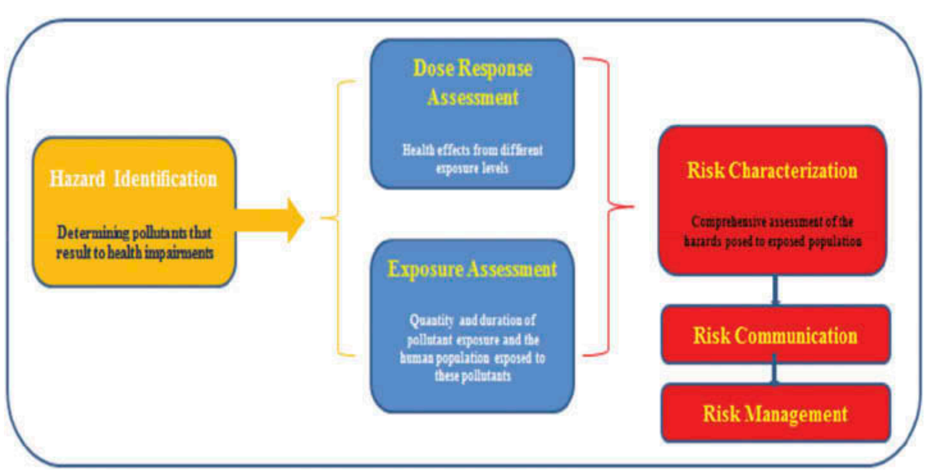
4.7. Risk assessment

The assessment of adverse health risks of BTEX compounds to pump attendants follows the general risk assessment paradigm developed by the National Research Council of the USA (Hayes, 1983) as seen in a simplified diagram in Figure 6. According to the framework which has been adopted by USEPA (USEPA, 2012) and other institutions, human health risk assessment includes four basic steps: namely hazard identification, dose-response assessment, exposure assessment, and risk characterization as shown in Figure 6.

Most occupational environments pose threats of exposure to chemical, particulate, radiological or other environmental hazards to persons within their vicinities (Baxter, Tar-Ching, & Anne Cockcroft, 2010). This exposure or human contact with contaminants leads to a dose that accumulates in the human body. The exposures and the resulting doses may result in adverse health effects. Exposure assessment is the process of evaluating these exposures. It may be carried out for a number of reasons, such as regulatory compliance, source characterization and evaluation of controls, and occupational epidemiology studies.

Occupational epidemiology examines the relationship between disease attributable to work environments and the intensity and duration of exposure of causal factors (Duncan, 2009). It forms the basis upon which governmental safety standards and compensation policies for

Figure 6. Risk assessment framework (US EPA, 2012.



environmental and occupational exposure are based. The prime objective of occupational health is to protect the health of employees from adverse effects of work activities (CONCAWE, 2004).

4.8. Considerations for remediation

National legislation is the surest way to provide for safety and health protection of workers against hazards at work. Corporate organizations can, however, limit exposure of their workers to hazardous chemicals if they establish and implement unambiguous OSH Policy Statements and SOP guidelines or codes of practice for protection of personnel against exposure. These policies must identify point sources of BTEX and provide guidelines for reducing their exposure to man. It is important to provide adequate resources including personnel, training, PPEs, and medical surveillance to effectively implement these programs. Establish clear-cut communication lines for hazards characterization, community awareness and emergency preparedness.

Depending on the nature of the hazard, provide adequate and effective engineering and procedural controls. In the case of BTEX exposure at pump stations engineering controls, procedural controls, personal protection and personal hygiene must be applied at man-manned stations in tandem. Specific engineering practices can include the use of vapour recovery units for discharge and dispensing, and installation of leak controls. Management practices may include limiting exposure time and training on the hazards of specific compounds.

It is also important to conduct regular health risk assessment of hazards and communicate to all parties involved. Assessments must be measurable against established standards that are specific and realistic.

Lastly, all protocols, inspections, monitoring reports, analytical reports, medical surveillance and training programs must be monitored and documented. A self-audit of these programs is necessary during a review. This audit will reveal program shortfalls and recommend corrective actions which must be implemented.

5. General conclusions

Various factors including weak occupational, social and health and safety framework and inappropriate pump infrastructure installations are implicated for the lack of occupational safety protocols at pump stations. In Ghana and in most parts of Africa, all pump stations are man-manned and without vapour recovery systems. Ghana is yet to pass the OSH legislation and enact laws and standards for exposure to volatile organic compounds (VOCs) at occupational settings. There is also a general lack of awareness for the adverse effects of hazardous VOCs. It is, therefore, necessary for Oil Marketing Companies and Pump Managers to make conscious attempts to protect their personnel against gasoline vapour since exposure to these compounds has been determined to be a major health risk.

Since exposure to BTEX above threshold levels is inherently dangerous the monitoring of BTEX exposure at pump stations by the regulatory agencies is essential for early warning detection associated with the release of high levels of these hazardous and toxic pollutants, and in estimating the potential exposure risks to workers.

Funding
The authors received no direct funding for this research.

Competing Interests
The authors declare no competing interests.

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Citation information
Cite this article as: Occupational exposure of benzene, toluene, ethylbenzene and xylene (BTEX) to pump attendants in Ghana: Implications for policy guidance, Francis Atta Kuranchie, Prosper Naah Angnunavuri, Francis Attiogbe & Esi Nana Nerquaye-Tetteh, *Cogent Environmental Science* (2019), 5: 1603418.

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